REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-01-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
04-2001	Professional Paper	

4. TITLE AND SUBTITLE

Autonomous Vehicles and the Net-Centric Battlespace

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHORS

Fletcher, B.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Space and Naval Warfare Systems Center
53560 Hull Street
San Diego, CA 92152-5001

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

20011217 282

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Autonomous vehicles are playing increasing roles in the air / land / sea network of today's battlespace. As the Navy's lead laboratory for command, control, communications, ocean surveillance, and the integration of multiple-platform systems, Space and Naval Warfare Systems Center San Diego has a unique perspective on the development and utilization of vehicles for these applications. A variety of autonomous systems and their roles will be discussed including remote sensor platforms, communication relays, and work platforms. As these capabilities are developed, autonomous vehicles will become an integral component of the C4ISR (command, control, communications, computers, intelligence, surveillance, reconnaissance) network.

Published in Proceedings of the International Unmanned Undersea Vehicle Symposium, 24-28 April 2000.

15. SUBJECT TERMS

autonomous vehicles
net-centric battlespace

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	19B. TELEPHONE NUMBER *(Include area code)*
U	U	U	UU	5	Barbara Fletcher, D744	(619) 553-3859

Autonomous Vehicles and the Net-Centric Battlespace

Barbara Fletcher
Space and Naval Warfare Systems Center D744
San Diego, CA 92152
bfletch@spawar.navy.mil

INTERNATIONAL UUV SYMPOSIUM

International Unmanned Undersea Vehicle Symposium
April 24-28, 2000

Viking Hotel
Newport, RI 02840

AUTONOMOUS VEHICLES AND THE NET-CENTRIC BATTLESPACE

Barbara Fletcher
Space and Naval Warfare Systems Center D744
San Diego, CA 92152
bfletch@spawar.navy.mil

Abstract

Autonomous vehicles are playing increasing roles in the air / land / sea network of today's battlespace. As the Navy's lead laboratory for command, control, communications, ocean surveillance, and the integration of multiple-platform systems, Space and Naval Warfare Systems Center San Diego (SSC-SD) has a unique perspective on the development and utilization of vehicles for these applications. A variety of autonomous systems and their roles will be discussed including remote sensor platforms, communication relays, and work platforms. As these capabilities are developed, autonomous vehicles will become an integral component of the C4ISR (command, control, communications, computers, intelligence, surveillance, reconnaissance) network.

I. Overview

The battlespace of today encompasses air, land and sea domains, requiring full sensor coverage and communication across all boundaries. The resulting network of sensors, platforms and communication modes results in a net-centric grid as depicted in Figure 1. The mission at Space and Naval Warfare Systems Center San Diego (SSC-SD) is focussed on the implementation and the effective use of the grid. It is the Navy's research, development, test and evaluation, engineering, and fleet support center for command and control, communications, ocean surveillance, and the integration of those systems which overarch multiple platforms. This provides a unique perspective for the development of autonomous vehicle applications encompassing all types of systems: air, ground, and undersea. The role of these vehicle systems and their integration is of growing importance as part of the net-centric approach to warfare.

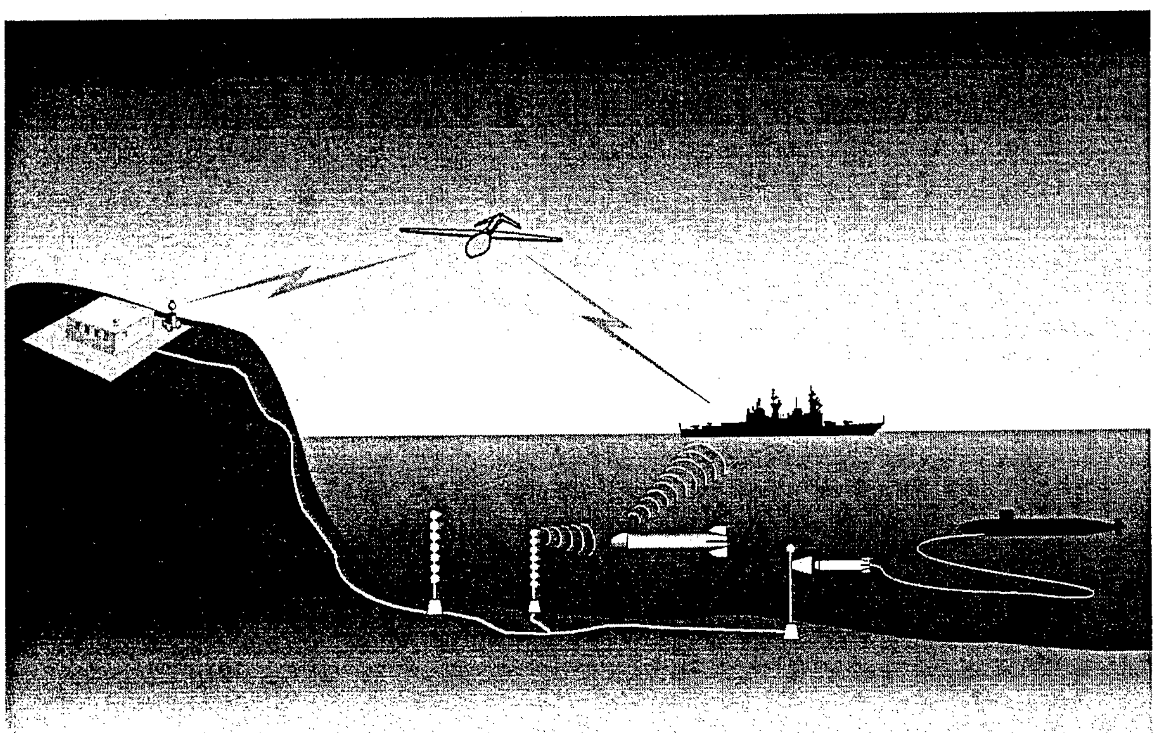

Figure 1: The Net Centric Battlespace

A. Missions

Inside the larger mission areas of C4ISR, there are a number of tasks well suited to implementation by autonomous vehicles (Figure 2). At the base of the pyramid is the collection of data, usually by sensors deployed at the sites of interest. Next, the data must be communicated to a central location where it is integrated with other data and interpreted within the context of the situation. Based on the interpretation, decisions are made as to the appropriate actions to be taken. Finally, the action is implemented, often requiring verification, which in turn is provided by sensors, restarting the cycle.

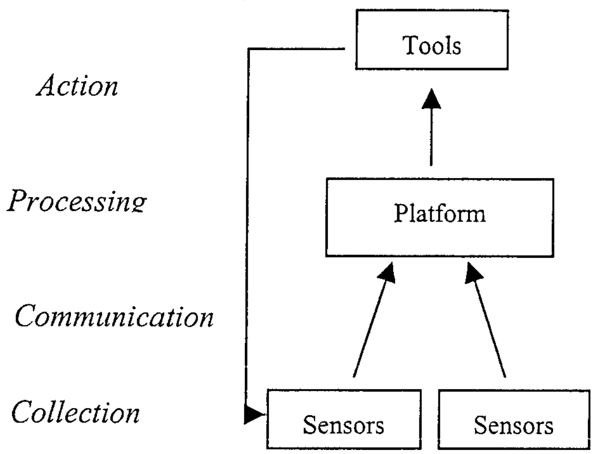

Figure 2: Information Tasks

B. Vehicle Roles

Autonomous vehicle systems play a key role in many of these mission tasks. They are an effective means of deploying surveillance sensors in air, land, and sea, providing the data required for comprehensive situation awareness and understanding. Various communications modes are facilitated with vehicle systems, be it underwater or over the horizon, providing connectivity without exposing troops or platforms to hazardous situations. Vehicles are also key in cross-platform integration, bringing shore-based data to offshore platforms and vice-versa. Compatible and integrated systems are essential for the continued evolution and performance of these missions.

To address the varied roles, a wide variety of vehicle systems have been developed at SSC-SD over the past 30 years. These include many teleoperated systems for land, air, and undersea use. As the missions have evolved, so have the technologies, leading to the more capable, autonomous systems described below. Additionally, by virtue of the SSC SD mission, many of the communications techniques by which these vehicles are linked are developed by SSC SD.

II. Vehicles as Sensor Platforms

Use of an autonomous vehicle as a sensor platform confers multiple advantages in the net-centric scenario. First and foremost is the extended reach possible. An autonomous system is not limited by a tether or other communication constraints. Second, the independence of an autonomous system allows it to operate discretely, with a minimum of exposure of manned assets. Combined with the reach, this means that an autonomous system may now penetrate previously denied or unsafe areas. Finally, continuing development is leading to the ability to deploy multiple systems, resulting in an extended network of sensors able to provide critical data in a timely fashion. SSC-SD has developed a number of systems and enabling technologies directed at achieving these goals.

A. Undersea

SSC-SD has developed a wide variety of autonomous underwater vehicles over the past 20 years, building on their experience in remotely operated vehicles. Systems such as the CURV, the Nozzle Plug, Mine Neutralization Vehicle, and Advanced Tethered Vehicle have provided a strong technology and application base for advanced system development.

Free Swimmer: Two Free Swimmer vehicles were produced by SSC-SD in the Experimental Autonomous Vehicle program, funded by the US Geologic Survey in the early 1980's. As testbeds, they demonstrated a wide variety of advanced concepts and technologies including autonomous pipeline following, supervisory control, autonomous mission planning, neural network controlled sensor, manipulator coordination, expendable fiber optic links, acoustic navigation, and underwater wet-mateable fiber optic connectors. While the free-swimmer vehicles themselves are currently inactive, the technologies developed with them are evident throughout the vehicle community.

Advanced Unmanned Search System (AUSS): The need for a deep ocean search capability drove the development of AUSS, demonstrated in 1992. Unhampered by a physical tether, AUSS uses an acoustic data link for supervisory control of the vehicle. All critical vehicle and mission control loops are closed on the vehicle, allowing autonomous performance of basic mission tasks such as transiting to a given location, hovering, and executing pre-programmed sonar and optical search patterns. Sensor data from the onboard side-looking sonar, forward looking sonar, and electronic still camera is compressed and acoustically transmitted to the surface. At any time, the surface operator may designate a target for closer investigation. If it

proves to be a false target, the search may be easily resumed. Designed to operate to a depth of 20,000 feet, the AUSS vehicle is 17' long, 31" diameter, with a cylindrical graphite epoxy pressure hull with titanium hemispherical ends. During its sea tests in 1992, AUSS demonstrated side-looking sonar search at 5 knots, detailed optical inspection, sustained search rates up to one square nautical mile per hour, and operation at a depth of 12,000 feet. The system remains intact and is on standby for any potential requirements.

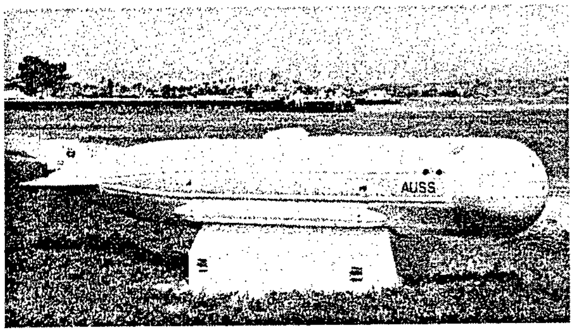

Figure 3: The Advanced Unmanned Search System (AUSS)

B. Land

In addition to undersea robotics, SSC-SD has played a significant role in ground robotics including the Ground Surveillance Robot, GATERS Teleoperated Vehicle, and the Surrogate Teleoperated Vehicle. Autonomous developments include ROBART I, II, and III, and the Mobile Detection, Assessment and Response System (MDARS). Started in 1988, MDARS provides automated intrusion detection and inventory assessment capability for DOD warehouses and storage sites. The goal is to provide multiple platforms performing random patrols within assigned areas. Separate indoor and outdoor systems are under development. The indoor system is based on the Cybermotion K2A Navmaster mobility base, and the outdoor mobility platform was developed by Robotic Systems Technology. System requirements are similar for both systems: the ability to navigate in a semi-structured environment. Novel features detected by the robot are assessed as to threat level, and appropriate action taken. The human operator is involved only when necessary. The indoor system has been in operation for over 2 years at a beta test facility at Camp Elliot in San Diego, and at a Defense Logistics Agency warehouse in Alabama. Operational fielding of the system is planned for 2000. Key portions of the outdoor system were demonstrated in 1996 and 1997, and development continues.

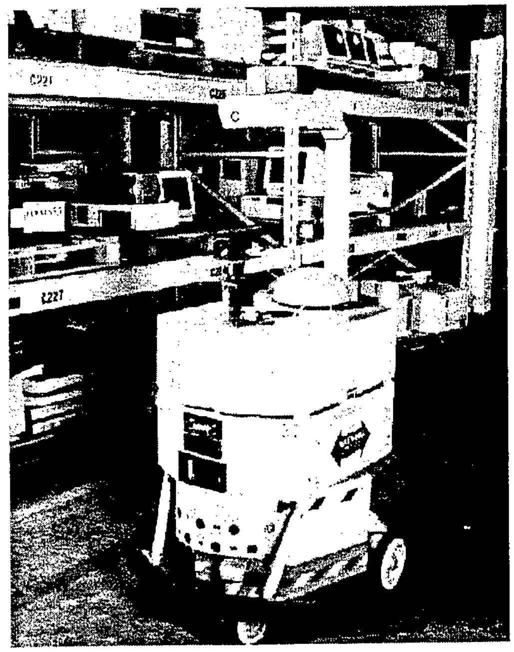

Figure 4: Interior MDARS

C. Air

Unmanned air vehicle (UAV) systems have also been developed at SSC-SD, starting with the Airborne Remotely Operated Device in the early 1980s. More recently, the Multi-Purpose Security and Surveillance Mission Platform (MSSMP) has been developed to provide a rapidly deployable, extended range surveillance capability. MSSMP system requirements include high mobility, operation over low bandwidth tactical radio links, long endurance surveillance capabilities, and the ability for one operator to supervise several systems. Based on the Sikorsky Cypher enclosed-rotor unmanned air vehicle, MSSMP carries a sensor package of a visible light video camera, infrared video camera, and a laser range finder, all mounted on a pan and tilt unit. As with MDARS, most sensor processing is performed on board, alerting the human operator only when a target of interest is detected. The system has been successfully demonstrated for several missions including a simulated counter-drug operation in May 1996 and urban terrain reconnaissance support in January 1997.

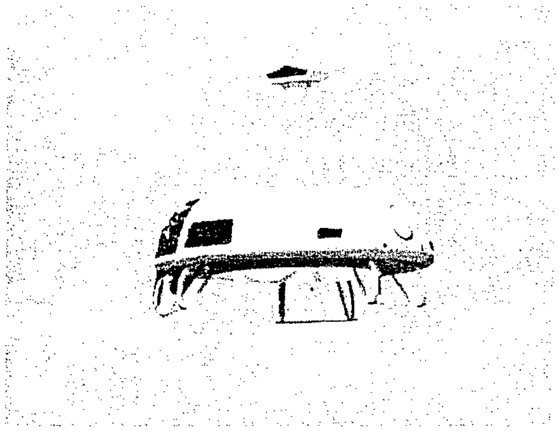

Figure 5 The Multipurpose Security and Surveillance Mission Platform (MSSMP)

III. Vehicles as Communication Aids

One of the emerging roles for autonomous systems is that of communication relays within the net-centric grid. As with the sensor platform role, use of autonomous vehicles confers multiple advantages. Their extensive reach permits timely communication with remote sites without undue exposure of platforms. This is equally effective for a submarine communicating with an undersea sensor grid or a ground base communicating over the horizon to forward deployed troops. SSC-SD is currently investigating a myriad of ways that vehicles can function as communication links within the context of larger systems being developed.

A. Undersea

The undersea environment presents extreme challenges in communication in terms of rate, bandwidth, and covertness. To address these issues, both relevant technologies and systems development must be considered.

Communication Technologies: Efforts at SSC-SD have been directed at providing high data rate transmissions for C3I (command, control, communications, intelligence) missions, real time communications links across platforms, and data recovery from undersea sensor packages. To these ends, both acoustic and fiber optic based systems have been developed. In support of the AUSS vehicle, a vertical path acoustic telemetry system was delivered with a range of 10 km and a data rate of 1200- 4800 bits/ second. An acoustic diversity telemetry system was also developed and transferred to industry where it was used with other vehicle systems. The use of fiber optic micro-cable was pioneered at SSC-SD with the development of the production process and its incorporation into several systems including the Nearterm Mine Reconnaissance System (NMRS).

Flying Plug: The Flying Plug vehicle system (Figure 6) was developed as a means of transmitting large quantities of data underwater via the expendable fiber optic micro cable. A small vehicle, the Flying Plug is launched from a support platform, paying out micro cable as it goes. Control functions are performed on the host platform via the cable, to maintain vehicle simplicity. The plug homes in on and docks with a reusable Socket autonomously, completing the connection between the host platform and the outside world. The Socket provides both acoustic and optical homing aids, as well as the latching mechanism required for the wet-mate optical connection. After the data transfer is complete, the plug detaches from the socket and may either be scuttled or retrieved for refurbishment. The Flying Plug was demonstrated in 1996 and is a key part of the Distributed Surveillance Sensor Network (DSSN). The objective of DSSN is to investigate the applicability of using small, inexpensive undersea vehicles for surveillance applications and submarine connectivity. Autonomous undersea vehicles gather data and periodically dock with undersea stations to dump data, recharge batteries, and receive new instructions. The data is retrieved by way of the Flying Plug providing the critical communications link to the Fleet

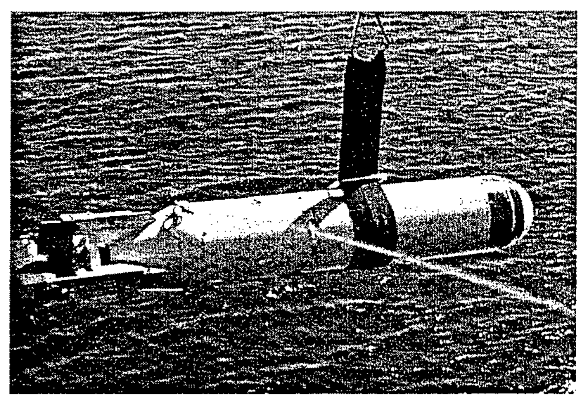

Figure 6: The Flying Plug

B. Air

Unmanned air vehicle systems can also perform communication and relay functions. Current SSC-SD UAV efforts include defining the roles of the imagery dissemination node for Global Hawk flights, supporting the integration of UAVs into Non-combatant Evacuation Operations, supporting the development of a submarine launched UAV, internetting ground sensors and undersea sensors via UAV communications relay, using UAVs to send

target track updates to precision targeting stations, and a collaborative US/UK effort to identify how UAVs can help solve the time critical targeting problem in the littoral region. The UAV Initiative is developing C4ISR tools for the warfighter including sensor packages, data , and command and control that are integrated with Navy tactical systems.

IV. Vehicles as Implementers

After the data has been collected, communicated to the central nodes, and processed, it is often desirable to be able to act upon it in a timely and appropriate fashion. Typical military actions may include firing on a target, intercepting a target, retrieving an object, or neutralizing a threat. Some of these functions are already routinely performed by autonomous systems- witness the use of torpedoes and cruise missiles. Nonetheless, the field is wide open for the expansion of autonomous work capabilities.

A. Undersea

Autonomous undersea work is still in its infancy, but much ground has been covered by remotely operated systems such as the Advanced Tethered Vehicle (ATV) and the Mine Neutralization System (MNS). The neutralization capabilities of the MNS can now be performed by one-shot disposable systems such as the Archerfish and SeaFox. With the continuing development of small AUVs, autonomous mine neutralization is not far off. General work tasks are more difficult to perform autonomously due to their more complex and relatively unpredictable nature. However, as systems are designed for use with autonomous vehicles, more complex operations will be possible, further enhancing the overall capabilities.

V. Conclusions

Autonomous vehicles can and are playing ever increasing roles in the Net-Centric battlespace. The extended range and covertness of autonomous sensor platforms allow collection of data from ever increasing areas. Communication of the data between platforms can be enhanced by vehicle means, leading to more complete and efficient data collection and processing. Finally, the ability to perform various tasks autonomously will continue to develop with vehicles as integral parts of the battlespace network.

References

For more information on these and other SSC-SD efforts, please consult the web page at:

http://www.nosc.mil/robots/

The systems discussed are related to the subject matter of one or more U.S. Patents assigned to the U.S. Government, including Patent No. 4,857,912; 5,034,817; 5,111,401; 5,202,661; 5,493,273; 5,659,779; and 5,812,267. Licensing inquiries may be directed to:

Harvey Fendelman, Patent Counsel
Space and Naval Warfare Systems Center
Code D0012
San Diego, CA 92152-5765
(619) 553-3001